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Energy Conservation in School Facilities

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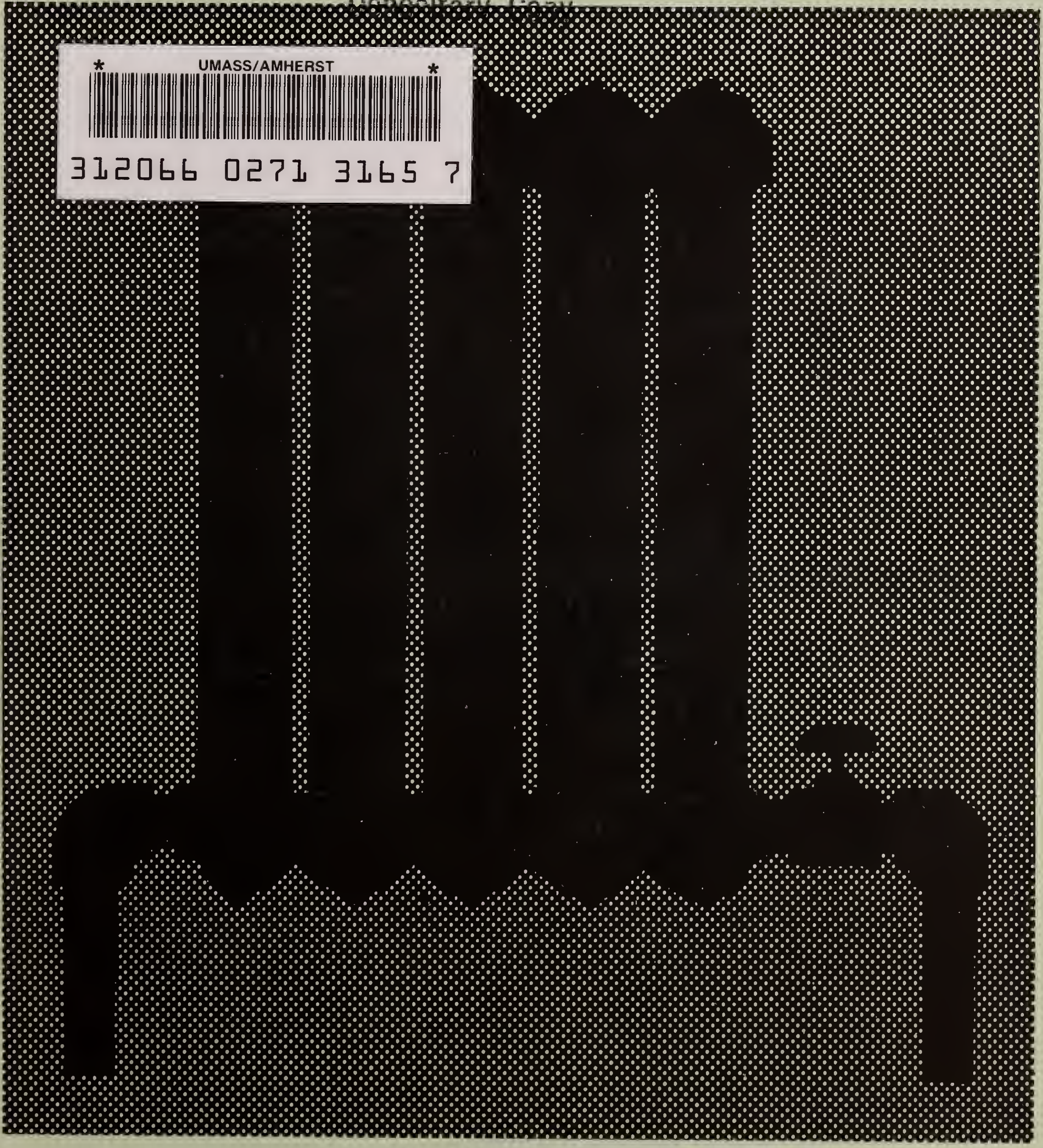

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ENERGY CONSERVATION IN EXISTING SCHOOL FACILITIES:

AN OVERVIEW

INTRODUCTION

According to American School and University magazine's annual Maintenance and Operations Cost Study, the median U.S. school district spent, in 1972, about $270 for each 1000 square feet. Estimates by the National Science Foundation indicate that today's buildings waste as much as 40 percent of the energy they consume. A quick calculation shows that taxpayers' money in the amount of $108 per 1000 square feet of educational plant went up the flue or out the window in a median district.

For school administrators, energy conservation in the design, construction, programming, and operation of school plants is both an essential and an ethical obligation. Essential because of the rapidly rising costs and unpredictable supplies of energy; ethical because the school district administration is both the steward of public monies and the leader of education in the community.

Recent experience is showing that energy conservation programs in schools can result in dramatic and immediate savings in tax dollars. Data gathered recently by Educational Facilities Laboratory (EFL) indicates that at least $4,000 per year in fuel and utility costs in a typical elementary school can be saved by reducing energy waste. The amount comes to over $10,000 per year in secondary schools. One small Colorado school district, Northglenn, through careful auditing of its energy usage patterns and through an organized program of energy conservation, is now saving in excess of $3,000 per month on its gas and electric bills.

It is hoped that the following discussion of energy conservation in school facilities will encourage district personnel to follow the successful examples of other school districts in reducing energy waste.

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Energy Conservation in Existing Facilities

When an educational facility is viewed as a system composed of plant, students and teachers, materials, support staff and program, one can identify three levels at which energy-saving strategies can be developed and implemented. These levels are:

1. The programmatic--the educational program and schedule of activities taking place at the school.
2. The operational--how the facility and its supporting systems are run to house and support these educational activities.
3. The physical plan and its operating system.

In general, programmatic and operational changes are only modifications in the way the existing facility is used and, therefore, usually entail little or no expenditure. On the other hand, changes to the physical plant or to one or more of its operating systems may be quite expensive.

Practical energy-saving strategies at each of the three levels are discussed in the following sections.

Programmatic Modifications

The educational program and schedule of daily activities are normally considered as a stable factor around which all other elements in the school system must revolve. The school's program reflects its primary function; the encouragement of learning and the sharing of knowledge. Most programs and schedules, however, have some room for trade-offs which can result in energy savings.

One such trade-off is the proper use of a plant at night or on weekends when it is less than fully occupied. If activities during these times are scheduled in such a way that all the spaces used are in a single heating or cooling zone, or are at least adjacent, the remainder of the plant can be shut down and the minimum of energy used.

The effect of programmatic changes on energy consumption is shown by a study of a "typical" Colorado school commissioned by the Colorado Department of Education. Using a computer simulation package, the study discovered the following energy variations resulting from variations in scheduling:

> Shutting down the school completely during Christmas Vacation and the month of January could result in an annual heating fuel savings of 23.9 percent.
>
> Extending Christmas Vacation another week could result in heating fuel savings of 5.8 percent per year.

> Starting school as late as 11:00 a.m. in the winter and running later in the afternoon would save only about five percent of the heating fuel per year.
>
> Using the school on a year-round basis, requiring air-conditioning in the summer months, would add 61.2 percent to the annual fuel and electricity bill.
>
> By turning heat on at 7:00 a.m. and off at 3:00 p.m. indicates that actual fuel consumption could be reduced by 13.8 percent annually.

Another scheduling technique that encourages energy conservation involved programming space use so as to place visual tasks in areas of specially designed lighting. This procedure can save considerable electrical energy by allowing a reducation in the general lighting level. In addition, visual tasks themselves may be modified. For example, the reading of #2 pencil on manila paper requires about fifty times as much light as reading felt-tip pens on matte white paper.

Operational Modifications--Cutting Waste in Building Lighting

There are three ways of reducing a school plant's waste of lighting energy. These may be used separately or in concert. They are: (1) reduce the number of lamps; (2) turn off the lamps in unoccupied spaces; and (3) make use of natural lighting when available.

1. Reducing the number of lamps: Lighting wattage in existing buildings may be reduced either by removing a percentage of flourescent tubes or by replacing incandescent lamps with bulbs of lower wattage. (Table I shows the annual costs of maintaining various lighting levels.) If this approach is used, reductions in teaching space lighting levels should be based upon careful consideration of what amount of lighting is appropriate.

Programs of this sort have been implemented in school districts all over the country. The facility director of an eastern district reported that since voluntary light use reduction efforts rapidly lose their ferver, the only way he can achieve his desired savings is by removing tubes. The director of an energy conservation program in a West Coast district reported that he had 500 watt incandescent bulbs in classrooms replaced with 350 watt bulbs over a weekend and space users never noticed the difference.

2. Voluntary light turning-off programs: The failure of Americans to turn off lights in rooms they leave is so notorious that a few years ago an American President was the butt of humor because of his attention to this detail.

TABLE I

COMPARATIVE ANNUAL ELECTRICAL CONSUMPTION AND COSTS FOR VARIOUS LIGHTING LEVELS

(28,000 square foot plant, $0.025 per KWH)

	School Plant Used 9 months Per Year	School Plant Used 12 Months Per Year
30 footcandles	37,750 KWH ($ 944)	52,100 KWH ($1302)
50 footcandles	64,200 KWH ($1600)	88,500 KWH ($2215)
70 footcandles	85,600 KWH ($2140)	118,500 KWH ($2960)
100 footcandles	128,600 KWH ($3210)	177,500 KWH ($4

> Few school buildings achieve more than 75 to 80 percent space utilization and if lights were conscientiously turned out in vacant spaces, up to one-quarter of the electrical bill could be saved with no change in lighting levels.

Numerous school districts and institutions of higher education have instituted programs to encourage the turning off of unused lights and other equipment by their facilities and students. Some of the activities by zealous savers can have comical results as anyone who has sat in a suddenly-darkened office cubicle or toilet stall can attest. Unfortunately, the success of these programs seems to fluctuate in an inverse relationship with the availability of gasoline.

Another approach, somewhat more consistent in its results, is to appoint student or staff monitors with responsibility for turning off lights when a room is empty and to periodically check the rooms in the plant for use.

3. Use natural light if you have it. If a building receives natural light through windows and skylights, the use of artificial lighting in the rooms should be adjusted accordingly. Some older school plants have separate switching circuits for banks of lights near the windows, a useful idea which could be added to all school plants with large window areas and, if properly used, could result in considerable energy savings. A study indicates that each linear foot of properly designed window (measured along the sill) can save up to 100 kilowatt-hours per year.

Cutting Waste in Heating and Cooling

The maintenance of a healthful and comfortable interior environment requires that the temperature and humidity be maintained within the "comfort zone" of conditions illustrated in Figure 6. Although conditions are often expressed as a single set of figures (such as 75°F, 50 percent relative humidity), an examination of Figure I shows that comfort conditions are actually a range of values, slightly different for summer and for winter and for different activity levels.

In an existing plant, maintenance of these desired conditions can be assured (with minimum energy consumption) by taking three steps: (1) setting the thermostats lower in winter and higher in summer; (2) reducing and controlling the amount of outside air taken in; and (3) using appropriate setbacks when the plant is not occupied.

1. Change thermostat settings: The study sponsored by the Colorado Department of Education found that reducing the thermostat setting (room temperature in classrooms from 75°F to 68°F in winter could save an estimated 23.4 percent of the annual heating fuel consumption. From an examination of the comfort zone in Figure I, the reader can see that a setting of 68°F is still within the range of comfort, provided that the humidity level

is not too high. Spaces in which more rigorous activities take place can be further reduced in temperature; in fact, such reductions are beneficial to the person engaging in these activities. The following figures are given for space temperatures by the New York State Education Department's "Energy Usage Guidelines:"

Classrooms	68°F
Shops	63-65°F
Gymnasiums	63-65°F
Storage and other non-student spaces	50-55°F

The wearing of suitable clothing, especially covering the arms and the ankles, increases comfort over a broad range of temperatures and the school should recommend warm apparel in winter and cool in summer.

2. Control outside air intake: Outdoor air is introduced into a building in two ways--intentionally for the purposes of ventilation and air freshening, and unintentionally through flaws in the building fabric and by the opening and closing of doors and windows. Whenever outside air is introduced into the building, it must be treated--heated or cooled--to match the conditions of the air in the spaces of the building. Up to one-half of the total heating and cooling bill may come from this treatment of intentional and/or accidental outside air intake.

Controlling outside air introduction so that only as much air as is required is brought into the building is one major energy savings in school plants. In buildings with mechanical ventilation, this control includes sealing of the plant against accidental introduction of outside air, or "infiltration," checking the settings of outside air intake dampers to insure that only the desired amount of air is actually being introduced, and shutting off the outside air fans when the plant is not occupied. EFL research indicates that the operation of intake and exhaust fans during unoccupied hours is a major cause of energy waste.

An energy study, undertaken in Fairfax County, Virginia, estimated that in buildings relying upon intake and exhaust fans, a reduction of 50 percent in the outside air intake is possible. This reduction, which still puts ventilation rates above the minimum requirements, would result in annual energy savings of about 25 percent. In a typical secondary school, this means an annual savings of about $11,000 with no investment.

Control of outside air introduction in buildings relying on natural or gravity ventilation is trickier, but taking appropriate action, such as weather-stripping windows and sealing cracks, can still result in energy savings. The Fairfax computer simulations put these savings at about 35 percent if the level of outside air introduction could be held to recommended levels.

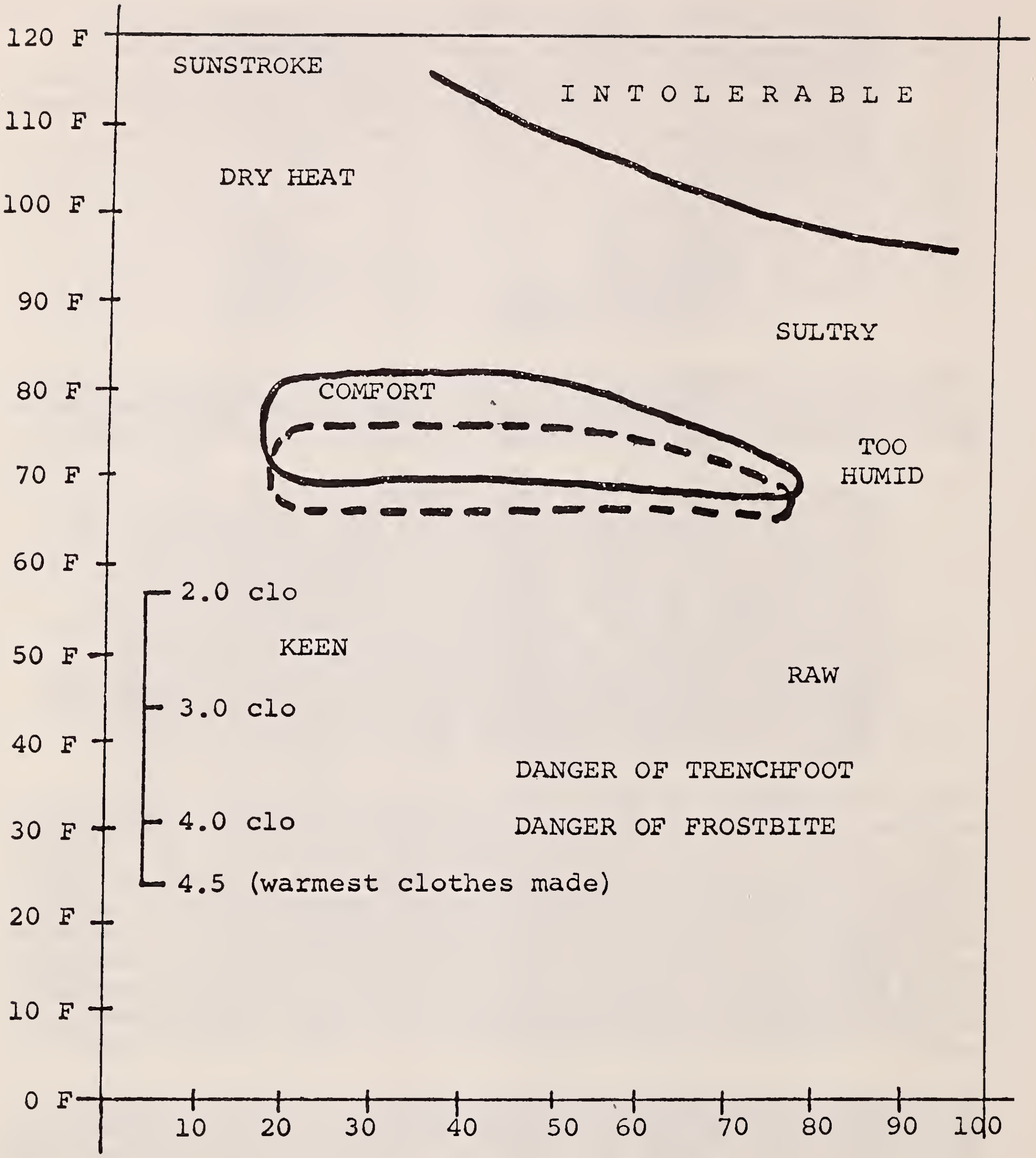

FIGURE I

Human Comfort Zone

SOURCE: Victor Olgyay, Design with Climate, pp. 19-24.

3. Setback of the system: Appropriate setback of the mechanical system during unoccupied periods is another source of energy savings which offers big results for little cost. Although most buildings built in the last three decades are equipped with setback controls, EFL experience indicates that as many as one in three of these units may not be effective because of malfunction and a larger proportion because of improper use. This is to remind the reader that even if an energy-saving device is provided, a certain amount of supervision is necessary to insure that it is used and used properly.

In setback, the load on the mechanical system is reduced by allowing the inside temperature of the building during unoccupied hours to fall in the winter and to rise in the summer--in mild climates, the system may be completely turned off during these times. Most thermostats allow a heating setback to 55°F and other units are available which go lower than this figure. The Colorado and Fairfax county studies indicate that a setback of winter temperature to 60°F from 70°F (roughly the same as any 10° setback) will result in savings of from 12 to 20 percent of annual heating fuel consumption. For the Virginia high school mentioned earlier in this discussion, this means annual fuel cost savings of over $18,000.

Proper System Maintenance

It is a truism that well-maintained systems operate more efficiently. In spite of this fact, however, one energy expert has estimated that as many as 80 percent of school building mechanical systems operate improperly due to poor or nonexistent maintenance.

Part of this problem is due to the absence of appropriate training programs for custodial, maintenance, and supervisory personnel. Two notable efforts to alter this situation have offered to make their materials and assistance available through the IECL Clearinghouse. The Division of Engineering of the North Carolina Department of Education has an extensive and successful program of workshops and video tapes which are used to train plant custodians and maintenance personnel in proper maintenance and operations of their buildings. This program includes such energy-related topics as testing burner efficiency and manual shifting of electrical load to reduce peak demand.

The second program has been developed as part of a community college curriculum by the Portland (Oregon) General Electric Corporation (PGE) in cooperation with a community college and several area school districts. In this program, the community colleges offer regular courses for custodians and maintenance personnel with full credit available. PGE provides materials and instructors for the program. Further information about both of these and other programs can be obtained from the IECL Clearinghouse.

Energy Savings Through Plant Modifications

Assuming that a plant is operating relatively efficiently, that is, with little or no wastage of energy, it may be necessary to invest funds in the plant in order to achieve further energy savings.

An effective analysis of energy-saving strategies which require investment cannot be made without some form of life-cycle cost analysis.

Mechanical Systems

Wearing out of the system or of its components or the preparation of a cost/benefit analysis may indicate the advantage of replacing all or part of the mechanical system in an existing plant with one which has better energy consumption characteristics. For example, providing a separate water heater or a smaller supplementary boiler may result in fuel savings in mild climates. It may also be found that existing mechanical plants have surplus capacity which may be used for additions, other plants, or other uses.

Several manufacturers now produce systems which are designed to be placed into existing plants and which provide efficient heating, ventilating and/or cooling while making extensive use of salvageable portions of the plant's existing systems.

In plants with central systems, the use of a heat recovery device between the outdoor air intake and exhaust air streams should be considered. The estimate prepared for the Fairfax County energy study indicated that at the two secondary schools to which this technique was applicable, such devices would pay for themselves in 5.9 and 6.8 years respectively. The annual energy cost savings at each of the two schools would not be in the neighborhood of $16,200 with these devices.

Improved control systems can be fitted to most existing plants at moderate expense and can greatly reduce consumption and costs. Time-sharing computer control of building systems is also available in some locales.

Lighting Systems

Upgrading of the lighting system of a plant is a common element of most modernization programs. When such upgrading is done, the designer should be careful to select the most efficient type of lighting source and to design it for low general levels with higher levels only where needed. The higher the lighting output per watt of input power, the lower will be the energy consumption to achieve any desired level of lighting--Table II lists some available high output lighting systems.

Switching patterns for lighting should allow for use of daylight and for some flexibility of use. The exterior banks of lights should be switched, either manually or automatically by photoelectric cells, to permit turning them off when adequate natural light is available. Two-level switching may be provided and teachers instructed in its use, to allow varying light levels in the classroom to respond to different educational activities.

TABLE II

EFFICIENCIES OF VARIOUS LAMP TYPES

Fluorescent lamps provide 3 times the lumens per watt of a standard incandescent (filament) lamp.

Fluorescent lamps lose efficiency at their ends. Efficiency is gained by the use of fewer and longer tubes:

2 - 24 inch cool white lamps = 50 lumens per watt

2 - 48 inch cool white lamps = 70 lumens per watt

2 - 96 inch (800 MA) lamps = 73 lumens per watt

High Intensity Discharge (HID) lamps:

400 watt metal halide lamp = 75 lumens per watt

1000 watt metal halide lamp = 85 lumens per watt

SOURCE: Charles D. Gibson, "Energy Saving Efforts Related to Lighting" (paper read to Southwest Regional Conference of the Council of Educational Facility Planners, International, Sacramento, California, April 20, 1974).

SUMMARY

In this section, a number of techniques which may be used to conserve energy in existing plants have been introduced. An effort has been made to view the school as a system composed of a number of elements--plant, users, program, schedule--and to show how energy may be saved with each of these elements.

A great deal of energy can be saved, with little or no cost by looking at the energy that plants are actually doing and then by reducing excessive and unnecessary operations and activities. Squeezing this waste out can result in annual cost savings of at least $4,000 in a typical elementary school and in excess of $10,000 in a typical secondary plant. Modifications requiring investment can and will produce further energy and cost savings if wisely made--life-cost analysis can help direct these investments.

For Further Information

Energy Conservation and the Building Shell. Educational Facilities Laboratories, Inc. Menlo Park, California: July 1974, 28 pgs (available from BSIC/EFL, 3000 Sand Hill Road, Menlo Park, CA 94025, $3.00 postpaid).

The Economy of Energy Conservation in Educational Facilities. Educational Facilities Laboratories, Inc. New York: EFL, 1973, 81 pgs (available from EFL, 477 Madison Ave., New York, NY 10022, $2.00 postpaid).

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"Energy Crisis: What Schools are Doing about It." American School and University. (February 1974) pp. 53-60.

Technical Options for Energy Conservation in Buildings. U.S. Department of Commerce, National Bureau of Standards. NBS Technical Note 789. Washington: U.S.G.P.O., July 1973, 184 pgs (available as SD Catalog No. C13.46:789 from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402, $2.35 postpaid).

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